A18 / PROCESS FOR SELECTING THE VISUAL DISPLAY FORMAT USED FOR CRASH ALERTS IN THE THREE DRIVER INTERFACE STUDIES

Symbol Design

The design of the candidate visual crash alerts initiated with a review of the visual crash alerts tested in a previous study (Jovanis, Campbell, Klaver, & Chen, 1997), production symbols contained in the ISO 2575/1 (1996), and symbols proposed for adaptive and conventional cruise control systems. "Crude" candidate icon drawings were forwarded to designers from the Controls and Displays Center at the General Motors Design Center who assisted with the symbol review and design process. These designers were familiar with ISO graphics constraints and ISO vehicle orientation stereotypes. This brainstorming process resulted in the 10 refined candidate visual crash alerts shown and numbered in Figure 1. Symbols 1, 2, 4, 5, 8, and 9 were created by altering current or proposed symbols.

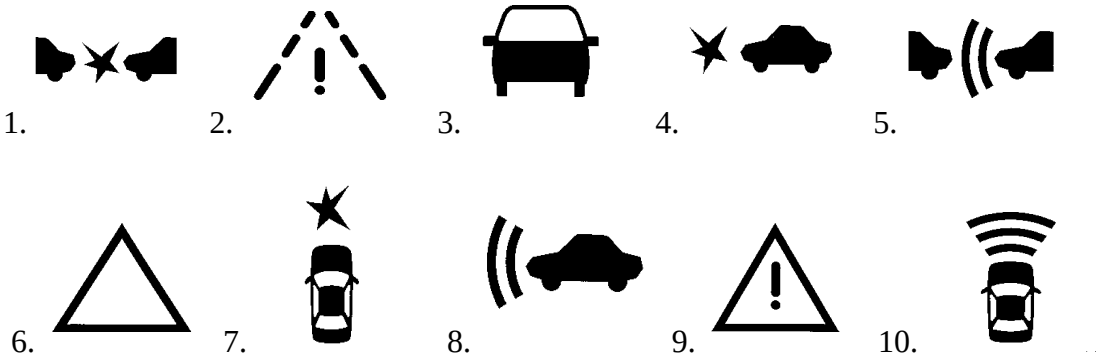


Figure 1 Visual Crash Alert Candidates

In general, the symbols conformed to the ISO 3461 (1976) guidelines for graphical symbols. With the exception of the tapered lines on the star-like crash symbol (symbols 1, 4, and 7), the symbols were designed using lines at least 2 mm in thickness. The symbols were then reduced to fit a 10-mm by 10 mm square, which was the size of the symbols used throughout the study.

Symbol Screening Process

The symbol screening process employed the ANSI Z535.3 (1997) procedures for evaluating candidate symbols. The first stage in this process is a *comprehension estimation procedure* used for the purpose of identifying poor symbols prior to open-ended comprehension testing. The

procedure involves informing participants of the intended message of a symbol and then asking them to estimate the percentage of the population they believe would understand the message of the symbol. According to the standard, only symbols with mean comprehension estimations of 65% or greater merit further testing in the second stage of this ANSI Z535.3 process, which involved an *open-ended comprehension procedure*. In this latter procedure, participant are provided a symbol with the appropriate context, and asked to provide written "open-ended" interpretations of the symbol. The ANSI Z535.3 recommended criterion for acceptance of a symbol is that 85% of participants provide correct interpretations of the symbol, and that a maximum of 5% of participants, provide interpretations considered critical confusions for the symbol.

Comprehension Estimation Testing

To conduct the comprehension estimation procedure, the 10 symbols shown in Figure 1 were printed on one sheet of paper with the intended message stated as follows. "You may be in danger of hitting the vehicle ahead unless you react immediately." The instructions explained that a symbol intended to convey the collision alert message would be shown as a display in a vehicle. Participants were asked to estimate the percentage of drivers they believed would quickly and accurately understand the intended message for each of the 10 symbols. The instructions stated that any number between 0 and 100 could be used for the estimation and that a number could be used as often as desired.

Two groups of participants completed the comprehension estimation procedure. The first group consisted of 12 males and 20 females working outside of the automobile industry. These individuals were operators at a hospital telephone center and students in an introductory engineering class at Wayne State University. These test participants ranged from 20 to 74 years old, with a mean age of 37.4 years (standard deviation=11 years). The second group of participants consisted of 42 male and 11 female industry experts working at General Motors Corporation and Ford Motor Company (The gender of 4 participants included in this analysis were not reported.). These experts had backgrounds in human factors, safety, adaptive cruise control systems, and/or forward collision warning systems. These test participants ranged from 24 to 63 years old, with a mean age of 41.9 years (standard deviation=11 years). These two participant groups provided an opportunity to view the representation of judgments made by industry insiders to that of naive individuals.

The mean comprehension estimates for each symbol are shown in Figure 2. The mean comprehension estimates for the two participant groups, non-automotive and industry experts, are shown separately. The pattern of comprehension estimates for the 10 symbols were similar for both groups. However, overall, the industry experts were more conservative than the non-automotive participants in their estimates. The two symbols with the highest mean comprehension estimates in both groups were symbols 1 and 5. For symbol 1, the two partial vehicles separated by a crash symbol, the non-automotive and industry groups provided mean comprehension estimates of 78.6% and 59.9%, respectively. For symbol 5, the two partial vehicles separated by curved lines resembling radar waves, the non-automotive and industry

groups provided mean comprehension estimates of 62.3% and 46.9%, respectively. None of the other eight candidate symbols had mean comprehension estimates over 50%.

Open-Ended Comprehension Testing

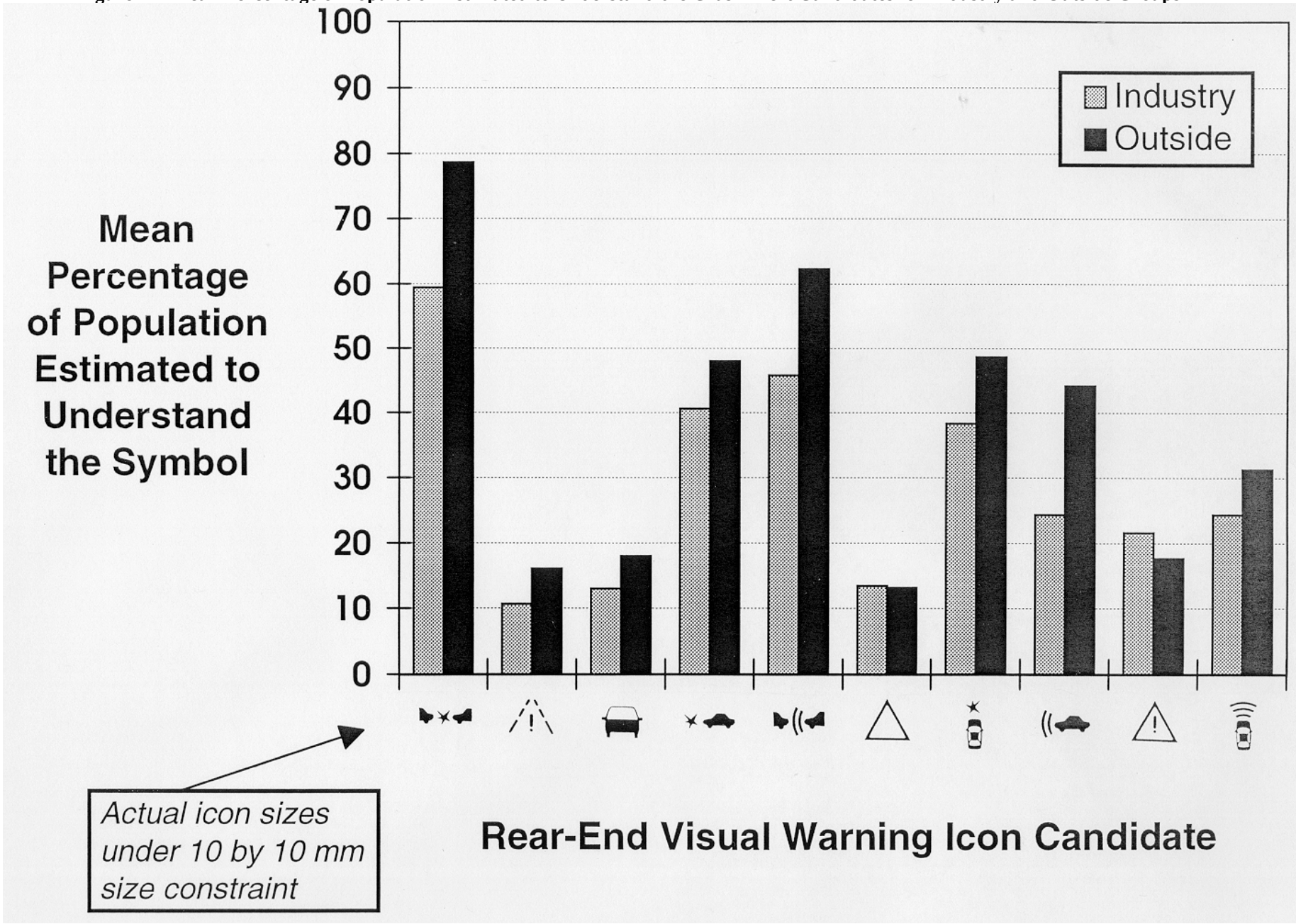
Symbols 1 and 5 were carried over from the comprehension estimation procedure as the candidate symbols for the second stage of testing required by ANSI Z535.3, an open-ended comprehension procedure. Symbol 1 clearly exceeded the 65% comprehension estimation criterion, whereas symbol 5 fell just below this criterion for the relevant, "non-expert" non-automotive group.

Two versions of a paper and pencil survey, one for each symbol, were constructed for the open-ended comprehension testing. The two versions of the survey were identical except for the symbol presented in this test. The survey contained two sections. The first section was an open-ended comprehension test requiring participants to provide written interpretations of the symbol, in accordance with the ANSI Z535.3 procedure. The second section of the survey employed the comprehension estimation procedure employed above to explore the effects of adding the capitalized word "WARNING" to the symbols.

In the instructions at the beginning of the survey, the importance of completing the survey in sequence was stressed. Participants were explicitly instructed to complete each page of the survey before turning to the next page. The instructions also included a discussion about how symbols are used to communicate messages without using words as recommended by the ANSI Z535.3 procedure. Examples of an incomplete and a complete message for a common symbol (i.e., fingers caught between gears) were given to introduce participants to the open-ended message writing task.

For the open-ended comprehension test, the symbol was presented along with a description of the context in which the symbol would appear. A given subject experienced the same symbol in three different contexts. Each successive description provided more contextual information.

Figure 2 Mean Percentage of Population Estimated to Understand the Crash Alert Candidates for Industry and Outside Groups



Context 1: "You are driving your car. You suddenly notice the following yellow/amber indicator on your dashboard light up."

Context 2: "You are driving your car. But you are distracted from the driving task. You are not concentrating on driving. You suddenly notice the following yellow/amber indicator on your dashboard light up."

Context 3: "You are driving your car. But you are distracted and you are not concentrating on driving. Your car is approaching another car. You suddenly notice the following yellow/amber indicator on your dashboard light up."

Each context, along with the symbol, was on a separate page. Context 1 was presented first followed by context 2 and then context 3. Participants were asked two questions for each context, which are shown below:

1. What would this dashboard indicator mean to you?

2. If you saw this indicator light on your dashboard would you take any action?

   If so, how soon would you take the action described?

   Nine response choices were given for this forced-choice question, shown below. (Participants were instructed to select one response.)

   - Immediately
   - Sometime before ending my drive
   - Immediately after ending my drive
   - Later that same day
   - The next day
   - Within 2-3 days
   - Within one week
   - Sometime after one week
   - Whenever it was convenient

The first question was an open-ended question that required participants to write out their interpretation of the symbol's message. Participants were instructed to provide as much detail as possible in their written responses.

In the second section of the survey, participants were shown four symbols; symbols 1 and 5 with and without the capitalized word "WARNING" printed below the symbol. The letters of this word were 3.2 mm in height, and the entire word extended approximately 3.5 mm beyond the left and right boundaries of the 10-mm by 10 mm square. The instructions informed participants that a symbol may be displayed in a vehicle as part of a collision alert system intended to reduce the number and severity of rear-end crashes. Participants were instructed that the symbol would be used to tell the driver the following message, "you may be in danger of hitting the vehicle ahead

unless you react immediately." Participants were then asked to estimate the percentage of drivers they believed would quickly and accurately understand this message for each of the four symbols. This page in the survey was covered by an extra sheet of paper to prevent participants from accidentally viewing the four symbols in this section before they completed the first open-ended section of the survey.

To recruit participants, members of CAMP recruited their families and acquaintances as contacts to then solicit naive participants for the survey. The contacts hand-delivered the surveys to participants, who mailed the completed surveys back to the experimenters in self-addressed stamped envelopes. Participants completed the surveys on a volunteer basis.

Thirty-four participants completed the version of the survey testing symbol 1, the crash symbol, and 30 completed the version testing symbol 5, the radar wave symbol. The crash symbol group of participants consisted of 14 males and 20 females, ranging from 18 to 73 years old, with a mean age of 44.7 years. The radar wave symbol group of participants consisted of 13 males and 17 females, ranging from 23 to 73 years old, with a mean age of 51.7 years.

For each of the three contexts, the responses to question (1) above were categorized into one of six general categories. The six categories were; responses mentioning a collision, responses mentioning proximity, responses mentioning warning, responses stating only an action, responses mentioning a possible error response, and other types of responses. Subcategories within each category are also reported here to provide more detail about the nature of the responses. Responses that included messages from more than one category were categorized into the category closest to the intended meaning of the symbol. For example, consider the following response given for symbol 5; "that at the speed you are going and the distance between cars it will be difficult to slow down in time without hitting the car in front of you." This response was categorized as "mentioning a collision" even though both proximity and the possibility of a collision were stated. Table 4 provides a sampling of the responses in each category.

The majority of open-ended responses for question (1) above were interpretations of the meaning of the symbol, and not simply statements about a driver's reaction to the symbol. Thus, few responses were classified in the action category. Further, participants were very descriptive in their interpretations of the symbols. Very few responses stated that the symbol was a warning without going into more detail about the nature of the warning (i.e., a warning about distance or a collision).

The percentage of responses classified into each response category for both symbols are shown in Table 5. For the crash symbol (symbol 1), the possibility of a collision was the most frequent response in each context. For the radar wave symbol (symbol 5), proximity to another vehicle or an object was the most frequent response. The crash symbol met the ANSI Z535.3 criteria of 85% correct responses in Context 1, Context 2, and Context 3, assuming collision, proximity, and action (brake the car) responses are correct. The crash symbol also generally met the ANSI Z535.3 criteria of no more than 5% errors, which are considered critical confusions for the symbol for both Context 1 and Context 3. For Context 2, two responses (5.9% of the total)

Table 4 Examples of Responses for the Six Response Categories Used in the Open-Ended Comprehension Test

Category	Example of response
Collision	
a) Not specific	"I'm going to hit another car."
b) Rear-end vehicle ahead	"Caution, you are about to hit a vehicle in front of you."
c) Head on	"Oncoming car is going to head on crash with me."
Proximity	
a) To car ahead	"You are following the car in front of you too closely."
b) Not specific	"Vehicle is in close proximity to another."
Warning	
a) Slow/stopped ahead	"The car ahead is slowing down..."
b) Object ahead	"I think it means that there is an object directly in front of you probably less than 5 feet."
Action	"Head up immediately and prepare to swerve or brake."
Error	
a) Rear-end from behind	"Proceed with caution, you are getting very close to the vehicle behind you."
b) Vehicle behind too close	"A vehicle is tail gating too closely."
Other	"Low fluids."

Table 5 Percentage of Responses in Each Category for Symbol 1 (Crash Symbol) and Symbol 5 (Radar Waves)

	Crash Symbol			Radar Waves		
Response Category	Context 1	Context 2	Context 3	Context 1	Context 2	Context 3
Collision						
Not specific	23.5%	41.2%	32.3%	10.0%	13.3%	20.0%
Rear-end vehicle ahead	17.7%	17.6%	17.7%	0.0%	3.3%	3.3%
Head-on	8.8%	5.9%	5.9%	3.3%	3.3%	3.3%
Total collision responses	50.0%	64.7%	55.9%	13.3%	20.0%	26.6%
Proximity						
To car ahead	32.3%	26.5%	32.3%	70.0%	40.0%	53.3%
Not specific	0.0%	0.0%	0.0%	6.7%	13.3%	3.3%
Total proximity responses	32.3%	26.5%	32.3%	76.7%	53.3%	56.6%
Warning						
Slow / stopped ahead	0.0%	0.0%	5.9%	0.0%	3.3%	0.0%
Object ahead	0.0%	0.0%	0.0%	3.3%	0.0%	0.0%
Total warning responses	0.0%	0.0%	5.9%	3.3%	3.3%	0.0%
Action	2.9%	0.0%	2.9%	0.0%	6.7%	13.3%
Error						
Rear-end from behind	0.0%	5.9%	0.0%	3.3%	0.0%	0.0%
Vehicle behind too close	2.9%	0.0%	0.0%	0.0%	0.0%	0.0%
Total error responses	2.9%	5.9%	0.0%	3.3%	0.0%	0.0%
Other	11.8%	2.9%	2.9%	3.3%	16.7%	3.3%

Table 6 Summary of Actions Stated for Each Context

	Crash Symbol		
Action	Context 1	Context 2	Context 3
Slow down/increase distance	41.2%	26.5%	35.3%
Brake only	20.6%	29.4%	29.4%
Brake, steer, chg. lanes	8.8%	5.9%	8.8%
Pay attn., use caution	2.9%	11.8%	0.0%
Stop	2.9%	0.0%	5.9%
Not specific	8.8%	14.7%	17.6%
Pull off road	0.0%	2.9%	0.0%
Other (e.g., check lights, manual, etc.)	14.7%	5.9%	0.0%
None given	0.0%	0.0%	2.9%
Speed up	0.0%	2.9%	0.0%

	Radar Waves		
Action	Context 1	Context 2	Context 3
Slow down/increase distance	56.7%	30.0%	46.7%
Brake only	20.0%	36.7%	26.7%
Brake, steer, chg. lanes	3.3%	0.0%	3.3%
Pay attention, use caution	0.0%	6.7%	3.3%
Stop	6.7%	3.3%	6.7%
Not specific	3.3%	3.3%	0.0%
Pull off road	3.3%	3.3%	3.3%
Other (e.g., check lights, manual, etc.)	3.3%	13.3%	3.3%
None given	0.0%	3.3%	6.7%
Speed up	3.3%	0.0%	0.0%

stated that the driver's vehicle may be rear-ended (One similar response occurred in Context 1.) The responses classified into the other category mentioned the airbag, low fluids, headlights, or the seat belts.

For question (2) above, across the three contexts, an action was indicated in 99.0% and 96.6% of the responses to the crash symbol and radar wave symbol, respectively. Table 6 is a summary of the responses given for the action question. In each context for both symbols, the most common responses were that the driver would either slow down to increase the distance between vehicles or apply the brakes. Some participants stated that they would either brake, steer, or change lanes depending on the situation. The higher rate of "not specific" responses for the crash symbol compared to the radar wave symbol was a result of more responses such as, "yes, as soon as possible," being given for the crash symbol. When specifying how soon they would take the stated action in response to the crash symbol, for Context 1, Context 2, and Context 3, 91%, 94%, and 97% of participants responded they would take action immediately. The corresponding percentages in response to the radar wave symbol were 93%, 83%, and 90%, respectively.

In the second section of the survey, participants were asked to estimate the percentage of drivers in the population that they believed would quickly and accurately comprehend the intended meaning of the symbols. Participants provided estimates for both the crash symbol and the radar wave symbol, with and without the capitalized word "WARNING" printed below it. Table 7 shows the mean estimates for each group of survey participants. Both groups estimated the crash symbol with the word WARNING would be understood by the largest percentage of drivers, with estimates across the two groups within 2% of each other. In contrast, the estimates for the radar wave symbol appear to be strongly influenced by whether participants saw the symbol in the open-ended response portion of the survey. In all cases, adding the word WARNING to the symbol increased comprehension estimates by about 20%.

Table 7 Mean Percentage of Driving Population Estimated to Comprehend Symbols by Open-Ended Comprehension Survey Participants

	Symbol only		Symbol with word WARNING	
Symbol in survey	Crash Symbol	Radar Waves	Crash Symbol	Radar Waves
Crash Symbol	60.0%	31.2%	81.4%	58.1%
Radar Waves	58.0%	52.0%	79.2%	73.8%

Summary of Results from the Visual Display Format Selection Process

As a result of both the comprehension estimation and open-ended comprehension test procedures administered in accordance with ANSI Z535.3 process Symbol 1 (the two partial vehicles separated by a crash symbol with the capitalized word “WARNING”) was used for all three driver interfaces studies (i.e., Study 2, Study 3, and Study 4) as the visual crash alert display format. In conclusion, these results provided a sound empirical justification for the selection of visual display format used in the follow-up, closed-course driver-interface studies.